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FINAL REPORT

EVALUATION OF OPENER DESIGN AND PACKING FORCE ON CANOLA, WHEAT AND PEA

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Evaluation of Opener Design and Packing Force Requirements on Canola, Wheat and Pea
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FINAL REPORT - December, 1999

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1. ABSTRACT/SUMMARY

An understanding of how direct seeding implement opener design and on-row packing pressure influence crop emergence and grain yield would help producers in their selection of appropriate seeding equipment for their farm and soil conditions. A field trial was conducted at three locations in Saskatchewan between 1997 and 1999 to evaluate the effect of direct seeding opener and packer design in combination with on-row packing pressure on the emergence and grain yield of wheat, canola and field pea. The opener-packer combinations included a Bourgault spoon with both a steel V packer and a flat rubber packer, a Morris paired-row with both a steel V and flat rubber packer, and a sweep with 15 cm spread of seed followed by a 15 cm pneumatic tire. Packing was applied at 0, 74, 124, 174 and 224 lb/wheel. The 0 packing treatment was no wheel following the opener, or unpacked. The locations were selected to range in soil texture, and included a sandy loam (Sylvania), silt loam (Watrous) and heavy clay (Indian Head). On average, across the 9 site-years in this study, minimal packing (74 lb/wheel) had a positive impact on the establishment and grain yield of spring wheat, with increasing packing pressure above 74 lb/wheel showing no additional benefit. The highest packing pressure had a negative impact on the establishment of canola. Under the wet field conditions in 1999, over packing was observed in the emergence of all crops at all locations. The elastic growth habit of both canola and pea resulted in little grain yield effect from variations in crop establishment due to opener of packing pressure. Within specific openers, field pea was the only crop to show a response to packing with the sweep+pneumatic tire opener-packer combination. The sweep+pneumatic tire was also found to provide a slight grain yield advantage for wheat and peas, while no difference was observed for canola. For peas, the spoon was on average slightly better than the paired-row opener for yield, however, the exact opposite was observed for wheat. Little or no difference was observed between the V and flat packers for the spoon and paired-row openers. This supports our conclusion that minimal packing is necessary for crop establishment under the soil moisture conditions found with these openers in direct seeding systems.

We conclude that the advantages observed between opener-packer combinations in this study were minor and likely of little agronomic or economic significance to most farmers. The use of a packing wheel for furrow closure was beneficial to crop establishment in this study. Packing improved stand under dry conditions, however, over packing is a risk under wet soil conditions.

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2. EXECUTIVE SUMMARY

An understanding of how direct seeding implement opener design and on-row packing pressure influence crop emergence and grain yield would help producers in their selection of appropriate seeding equipment for their farm and soil conditions. A field trial was conducted at three locations in Saskatchewan between 1997 and 1999 to evaluate the effect of direct seeding opener and packer design in combination with on-row packing pressure. The opener-packer combinations included a Bourgault spoon with both a steel V packer and a flat rubber packer, a Morris paired-row with both a steel V and flat rubber packer, and a 15 cm sweep on 30 cm spacing with a 15 cm pneumatic tire. Packing was applied at 0, 74, 124, 174 and 224 lb/wheel. The locations were selected to range in soil texture, and included a sandy loam, silt loam and heavy clay. The following conclusions can be made from this research:

- On average, across the 9 site-years in this study, minimal packing had a positive impact on the establishment and grain yield of spring wheat, while the highest packing pressure had a negative impact on the establishment of canola. Under the wet field conditions in 1999, over packing was observed in the emergence of all crops at all locations. The elastic growth habit of both canola and pea resulted in little grain yield effect from variations in crop establishment.
- The sweep+pneumatic tire was found to provide a slight grain yield advantage for wheat and peas, while no difference was observed for canola. This occurred even though this opener was always inferior for wheat establishment at the clay loam soil site at Watrous. For peas, the spoon was on average slightly better than the paired-row opener for yield, however, the exact opposite was observed for wheat.
- Little or no difference was observed between the V and flat packers for the spoon and paired-row openers. This supports our conclusion that minimal packing is necessary for crop establishment under the soil moisture conditions found with these openers in direct seeding systems.
- Over packing is a risk under wet soil conditions, however, this was rarely reflected in final grain yields. We conclude that the advantages observed between opener-packer combinations in this study were minor and likely of little economic significance to most farmers.

C. TECHNICAL REPORT

C.1 Background

The development of conservation tillage production systems in Saskatchewan has been fostered by the reduction in the price of Roundup® herbicide, and the development of high clearance seeding equipment, in particular air drills. These seeding implements are capable of seeding through accumulated surface crop residue, while achieving positive seed to soil contact. One of the major advantages of direct, or no-till, seeding is the ability of the accumulated surface crop residues to maintain soil moisture for seed germination in dry climates. The use of on-row packing systems ensure closure of the seeder furrow and positive seed to soil contact. However, producers have expressed concern about the impact of packer wheel design and down pressure on the ability of crop seedlings to emerge from this often high moisture soil environment. In addition, what effect does the type, or design, of opener have on seed placement and crop emergence. The majority of seed bed packing research has focussed on tilled seed bed conditions and the role of coil packers in achieving crop emergence. Hultgreen (unpubl. data) evaluated packing systems with winter wheat, and found that on-row packing improved crop emergence and winter wheat grain yield.

C.2 Objective

The purpose of the research is to provide solid and precise information on the agronomic implications of different forms and methods of packing, and assist the producer in selecting appropriate packing systems for his farming systems and soil conditions. In addition, this work will identify the basic operative principles associated with packing to assist manufacturers in the design of their packing systems.

C.3 Materials and Methods

The effect of air drill opener, packer shape and packing pressure were evaluated in a field research study at Sylvania, Watrous and Indian Head, Saskatchewan between 1997 and 1999, giving 9 site-years per crop. Trial sites were selected to provide a range of soil and environmental characteristics (Table 1-3). The Sylvania site was selected for its sandy loam to loam soil, Watrous for its loam to silty-loam soil type, and Indian Head as a heavy clay soil location. The five opener-packer combinations, and five packing pressures, were evaluated in a two factor RCBD over year and locations, considered together as site-years (Table 4). Plot size was 3.1 m by 7.6 to 9.1 m in length, and seeded using a custom designed air seeder with openers on 30 cm spacing (build and operated by PAMI). Mono-ammonium phosphate fertilizer was seed placed at 28 kg P_2O_5/ha with all crops, while urea N was mid-row banded at 77 kg N/ha for canola and spring wheat. Sulphur and potassium fertilizer were broadcast applied to the plot area prior to seeding each year. Wheat (cv. AC Barrie), canola (cv. Innovator) and pea (cv. Carneval) were grown at each location as separate experiments. Wheat was seeded at 137 kg/ha, canola at 6.8 kg/ha mixed with 2.8 kg/ha of granular insecticide, and pea at 198 kg/ha with seed applied powdered peat *rhizobium* inoculant. Herbicides were applied as required to achieve optimum weed control.

Crop emergence was determined at 3-4 weeks post-seeding by counting the number of seedlings in 1 m of crop row, twice within each plot. At maturity crop yield was determined by harvesting the entire plot area using a small plot combine.

Data was analysed for each crop, across year-location (9 site-years total), using either ANOVA or GLM procedures (SAS Institute, 1989). In the combined analysis while opener-packer and packing pressure were considered fixed effects, site-year and interactions with site-year were considered random. Mean separation of packing pressure and opener-packer main effects were evaluated using $LSD_{0.05}$. Unless otherwise specified, a response was considered significant using an α=0.05.

C.4 Results and Discussion

Results will be presented from the combined analysis over years and locations for each crop (9 site-years) to illustrate the effect of opener-packer combination and packing pressure on the emergence and grain yield of canola, pea and wheat. Detailed analysis by crop over years at each location are included in Appendix 1.

Wheat Emergence and Grain Yield

Wheat crop emergence showed a definite response to packing and the opener-packer combinations evaluated in this study (Table 5). The absence of packing was inferior to some

packing, however, there was little difference in emergence as we moved from the 74 to 224 lb/wheel of packing pressure. The only exception to this was the sweep + pneumatic tire treatment, where wheat emergence progressively improved with increasing packing pressure up to 174 lb/wheel (Figure W1). The size of the difference in crop emergence was much larger than that observed for grain yield, indicating that the crop was capable of compensating for the variation in plant stand (Figure W2). However, while not significantly different, the addition of some packing alway resulted in a modest wheat yield response over the unpacked check for all openers.

With respect to packing pressure, considered across all openers, only at Indian Head in 1999 did increasing packing pressure actually result in wheat seedling emergence that was less than the unpacked check on heavy clay soils (Figure W3). At all other trial locations packing improved the emergence of wheat over the unpacked check. While a curvilinear response (improved and then declined as packing increased) was observed at a number of locations, these never resulted in seedling stands that were poorer than the unpacked check. At Sylvania in 1997, and Watrous in 1998 and 1999, increasing packing pressure above 124 lb/wheel was of no benefit to wheat emergence. Increasing packing pressure over the unpacked check showed a positive grain yield response at Indian Head in 1998 and 1999, and Sylvania in 1997 and 1999 (Figure W4). Increasing packing pressure above 74 lb/wheel showed no added benefit. These packing responsive trials were all rated as average to good for environmental conditions, indicating that the positive response was not due to dry seeding conditions. All other site-years provided really no grain yield response to increasing packing pressure, indicating that the crop could compensate final grain yield for variation in plant stand.

With respect to opener-packer combination, averaged across all packing pressures, the variability between the openers at each location confirmed that not one opener was best suited to all soil-environmental conditions sampled in this study. At Indian Head the spoon with either the V or flat packer tended to be the best treatment for wheat emergence, while at Sylvania on the sandy loam soils it was the sweep + pneumatic tire and paired-row opener which provided an advantage (Figure W5). However, at Watrous while the spoon and paired row openers were comparable, the sweep + pneumatic tire was definitely inferior in wheat seedling establishment. At Watrous, while dry conditions at seeding were experienced in both 1997 and 1998, the poor emergence response recorded with the sweep was also observed under good moisture conditions in 1999. With the exception of Sylvania in 1999, there was no relationship between grain yield and wheat seedling stand establishment response to opener type (Figure W6). In fact Where seedling stand was poorest with the sweep at Indian Head in 1999, it resulted in the best grain yield. The common pattern of the sweep treatment being inferior over all years at Watrous was not reflected in the grain yield response for this treatment.

Canola Emergence and Grain Yield

Canola response to opener-packer and packing pressure was completely different than wheat. On average across all 9 site-years of data, only the spoon + V packer showed any positive response to increasing packing pressure (Figure C1). At the 224 lb/wheel packing pressure with this opener there was a negative response to packing observed. All other opener-packer combinations showed a minor decline (not significant) in canola seedling stand with the addition of a packing

wheel and increased packing wheel weight (Table 5). The elastic nature of the canola plant, whereby branching and flowering allow it to compensate for poor plant establishment, resulted in no difference in grain yield response to packing pressure or opener-packer combination (Figure C2).

With respect to packing pressure, considered as a main effect across all openers, no significant site-year by packing pressure interaction was recorded for canola seedling establishment (Table 5; Figure C3). In general, all locations, at some time during the 3-years of the study, showed some negative response to increasing packing pressure on canola emergence. However, in 1997 at Sylvania a significant positive response to increasing packing pressure was recorded on canola grain yield. While all other site-years showed no grain yield response to packing pressure, this one positive response to packing resulted in a site-year by packing pressure interaction for canola grain yield (Figure C4).

The significant opener-packer by site-year interaction for canola seedling stand was recorded because of the variability that was recorded between openers both within locations and across site-years (Figure C5). For example, at Indian Head the narrow spoon opener provided superior plant stands in 1997 and 1998, however, was significantly poorer than the paired-row and sweep openers in 1999. With regards to grain yield, only at the Sylvania location did any specific trend emerge from the data (Figure C6). Use of the V packer with both the spoon and paired-row openers provided a minor canola grain yield advantage, with the flat packers and the sweep + pneumatic tire being similar but inferior. No attempt will be made to try and explain the significant site-year x opener x packer interaction for canola seedling stand.

Field Pea Emergence and Grain Yield

In general, the pea crop showed the least response to either opener-packer combination and packing pressure (Table 5). Only the sweep + pneumatic tire showed some response to increasing packing pressure for seedling emergence (Figure P1), however, this was not reflected in any grain yield response (Figure P2). The sweep + pneumatic tire resulted in the greatest soil disturbance, and we anticipated that there may be more benefit to packing with this treatment. The elastic growth habit of peas resulted in the crop compensating for the minor differences in plant stand, similar to canola.

When all site-years were considered together a significantly site-year by packing pressure interaction was recorded for both pea seedling stand and grain yield (Table 5). At Indian Head in 1998, Sylvania in 1997 and Watrous in 1997 we observed a positive response for pea seedling stand to increasing packing pressure (Figure P3). While Indian Head and Sylvania responses were recorded under years considered to have average moisture and temperature conditions, the positive response at Watrous in 1997 was recorded under dry spring conditions. More importantly is the result that at all locations in 1999, a wet and cool spring, the addition of packing reduced pea emergence relative to the unpacked check. Within trial locations, only at Sylvania was a significant year x packing interaction recorded, reflecting the positive response to packing in 1997 and negative response in 1999. The negative response to packing on plant stand at Indian Head in 1998 was reflected in a negative response on grain yield (Figure P4). Alternatively, the positive response to packing on emergence at Watrous in 1997 was reflected in

a positive grain yield response. In general, the packing response on peas was minor, with the least benefit of all the crops considered in this study.

Summarized across all trials, the sweep + pneumatic tire resulted in the best plant stands (not significant) for pea (Table 5). This response to a greater spread of seed was observed at Sylvania in 1997 and 1999, and at Watrous in 1998 and 1999 (Figure P5). At Indian Head in all years, and Sylvania in 1998 and Watrous in 1997, there appeared to be little or no difference between openers on pea seedling establishment. As found with wheat, a significant opener response was recorded for pea grain yield when averaged across all trial locations and years (Table 5). The sweep + pneumatic tire produced the highest grain yields, followed by the spoons and then the paired-row. However, within specific locations there were distinct differences. On the sandy loam soil at Sylvania the sweep continued to be the best opener, however, the paired row opener was inferior to the spoons. Comparing the effect of packer shape (V vs. flat) for the spoon and paired row openers indicated no establishment or grain yield differences (Table 5). On average, across all site-years, these results are similar for both canola and wheat as well.

Table 1. Soil type, texture, moisture, fertility, seeding date, harvest date, growing season precipitation and environmental conditions at Indian Head, Sylvania and Watrous in 1997.

		Soil Characteristics			%Soil Moisture†	Soil Fertility‡		Variety	Seeding Date	Harvest Date	Growing Season Precip.	Environmental Conditions§
Location	Soil Type	%Sand	%Silt	%Clay	0-4" Depth	N	P					
WHEAT												
Sylvania	Loam	41.8	37.2	21.0	23.7	41	25	AC Barrie	23-25 May	4 Sept	238 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	27.0	17	20	AC Barrie	14-17 May	23 Aug	142 mm	Poor
Indian Head	Hvy. Clay	9.5	27.4	63.1	36.0	30	10	AC Barrie	28-29 May	3 Sept	102 mm	Poor
PEA												
Sylvania	Loam	41.8	37.2	21.0	22.7	41	25	Carneval	23-35 May	20 Aug	171 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	27.1	25	25	Carneval	15-18 May	12 Aug	110 mm	Poor
Indian Head	Hvy. Clay	9.5	27.4	63.1	29.2	30	10	Carneval	28-30 May	28 Aug	96 mm	Poor
Canola												
Sylvania	Loam	41.8	37.2	21.0	23.2	41	25	Innovator	23-25 May	4 Sept	238 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	33.1	18	46	Innovator	14-16 May	14 Aug	111 mm	Poor
Indian Head	Hvy. Clay	9.5	27.4	63.1	38.3	30	10	Innovator	28-30 May	10 Sept	102 mm	Poor

†Gravimetric soil moisture determined from the 0-10 cm surface profile at seeding.

‡ N (NO_3-N) to 60 cm, and P to 15 cm.

§ Poor - periodic drought combined with heat and/or wind stress; Average - No extended dry periods. Heat and/or wind stress may have been yield resucing factors.

Table 2. Soil type, texture, moisture, fertility, seeding date, harvest date, growing season precipitation and environmental conditions at Indian Head, Sylvania and Watrous in 1998.

Location	Soil Type	Soil Characteristics			% Soil Moisture†	Soil Fertility‡		Variety	Seeding Date	Harvest Date	Growing Season Precip.	Environmental Conditions§
		%Sand	%Silt	%Clay	0-4" depth	N	P					
WHEAT												
Sylvania	Loam	41.8	37.2	21.0	29.5	¶		AC Barrie	May 14,17	3 Sept	224 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	25.6	16	41	AC Barrie	May 10-12	28 Aug	209 mm	Poor
Indian Head	Hvy Clay	9.5	27.4	63.1	34.0	#		AC Barrie	May 21,22	31 Aug	242 mm	Average
PEA												
Sylvania	Loam	41.8	37.2	21.0	27.6			Carneval	May 14,17	3 Sept	224 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	28.6	22	22	Carneval	May 11,12	11 Aug	209 mm	Poor
Indian Head	Hvy Clay	9.5	27.4	63.1	40.0			Carneval	May 21,22	31 Aug	242 mm	Average
CANOLA												
Sylvania	Loam	41.8	37.2	21.0	26.3			Innovator	May 14,17	3 Sept	224 mm	Average
Watrous	Silt Loam	14.3	58.5	27.2	27.9	15	18	Innovator	May 11,12	12 Aug	209 mm	Poor
Indian Head	Hvy Clay	9.5	27.4	63.1	39.4			Innovator	May 21,22	2 Sept	242 mm	Average

†Gravimetric soil moisture determined from the 0-10 cm surface profile at seeding.
‡N (NO_3-N) to 60 cm, and P to 15 cm (lb/ac)
§Poor - periodic drought combined with heat and/or wind stress; Average - no extended dry periods, heat and/or wind stress; Good - above average rainfall well distributed through growing season, moisture reserves adequate to cope with heat and/or wind stress.
¶ Soil samples were collected at Sylvania in 1998, however lost.
# Soil samples from Indian Head still to be analyzed.

Table 3. Soil type, texture, moisture, fertility, seeding date, harvest date, growing season precipitation and environmental conditions at Indian Head, Sylvania and Watrous in 1999.

Location	Soil Type	Soil Characteristics			% Soil Moisture†	Soil Fertility‡		Variety	Seeding Date	Harvest Date	Growing Season Precip.	Environmental Conditions§
		%Sand	%Silt	%Clay	0-4" depth	N	P					
WHEAT												
Sylvania	Loam	41.8	37.2	21.0	23.6	18	14	AC Barrie	May 8-10	Sep 15	274 mm	Good
Watrous	Silt Loam	14.3	58.5	27.2	30.9	24	27	AC Barrie	May 24-26	Sep 26	287 mm	Average
Indian Head	Hvy Clay	9.5	27.4	63.1	43.5	32	19	AC Barrie	May 28-30	Sep 24	355 mm	Good
PEA												
Sylvania	Loam	41.8	37.2	21.0	25.3	18	16	Carneval	May 8-10	Sep 15	274 mm	Good
Watrous	Silt Loam	14.3	58.5	27.2	32.6	20	28	Carneval	May 24-26	Sep 8	287 mm	Average
Indian Head	Hvy Clay	9.5	27.4	63.1	39.8	33	26	Carneval	May 28-30	Sep 17	355 mm	Good
CANOLA												
Sylvania	Loam	41.8	37.2	21.0	22.0	16	18	Innovator	May 8-10	Aug 25	274 mm	Good
Watrous	Silt Loam	14.3	58.5	27.2	31.4	18	31	Innovator	May 24-26	Sep 7	287 mm	Average
Indian Head	Hvy Clay	9.5	27.4	63.1	39.4	28	8	Innovator	May 28-30	Aug 30	355 mm	Good

†Gravimetric soil moisture determined from the 0-10 cm surface profile at seeding.

‡N (NO_3-N) to 60 cm, and P to 15 cm (lb/ac), N and P to 30 cm at Watrous

§Poor - periodic drought combined with heat and/or wind stress; Average - no extended dry periods, heat and/or wind stress; Good - above average rainfall well distributed through growing season, moisture reserves adequate to cope with heat and/or wind stress.

Table 4. Opener, packer and packing pressure combinations evaluated with wheat, canola and pea at Indian Head, Sylvania and Watrous in 1998.

Opener - Packer combination	
1. Bourgault spoon + steel V 2.5"	
2. Bourgault spoon + semi-pneumatic oval 3"	
3. Morris paired row + steel V 4.5"	
4. Morris paired row + oval 4.5"	
5. 12" sweep + pneumatic tire 6"	
Packing Pressure (lb/wheel)	
1.	0
2.	74†
3.	124
4.	174
5.	224

†There was one exception for the 74 lb/wheel weight, in that with opener - packer combination #4 (Morris paired row + oval 4.5") the weight was 86 lb/wheel.

Table 5. Combined analysis of seedling stand and grain yield for wheat, canola and pea at Indian Head, Sylvania and Watrous, 1997, 1998, and 1999.

	Wheat		Canola		Pea	
	Seedlings	Grain Yield	Seedlings	Grain Yield	Seedlings	Grain
Pr>f						
Site year	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Packing	0.0004	0.0012	0.0208	0.8576	0.7098	0.8370
Opener	0.3058	0.0300	0.6983	0.4913	0.0915	0.0303
Pack x Opener	0.0728	0.4952	0.9081	0.9628	0.0160	0.2959
Site x Pack	0.0002	0.0024	0.6234	0.0178	0.0123	0.0488
Site x Opener	0.0001	0.0001	0.0001	0.0094	0.0001	0.0001
S x P x O	0.5750	0.8209	0.0049	0.0590	0.8128	0.5043
CV	16	10	21	13	17	12
Packer †						
0	173 b	39.8 b	93 a	26.3	59	39.8
74	194 a	41.9 a	91 a	26.7	59	40.3
124	195 a	42.2 a	91 a	27.0	59	40.2
174	194 a	42.2 a	90 ab	26.7	60	40.2
224	190 a	41.9 a	85 b	26.9	60	39.6
Opener ‡						
Sp + V	190	40.5 b	92	27.6	57	40.2 ab
Sp + flat	195	41.0 b	86	26.4	58	40.1 ab
P-row + V	186	41.9 ab	92	26.6	60	38.9 b
P-row + flat	190	41.1 b	94	26.5	59	38.8 b
Sweep + tire	184	43.5 a	85	26.5	63	42.1 a

†Packing main effect means followed by the same letter are not significantly different $LSD_{.05}$.
‡Opener main effect means followed by the same letter are not significantly different $LSD_{.05}$.

Figure W1. Wheat seedling opener-packer by packer pressure response – Mean for 9 site-years, 1997-1999.

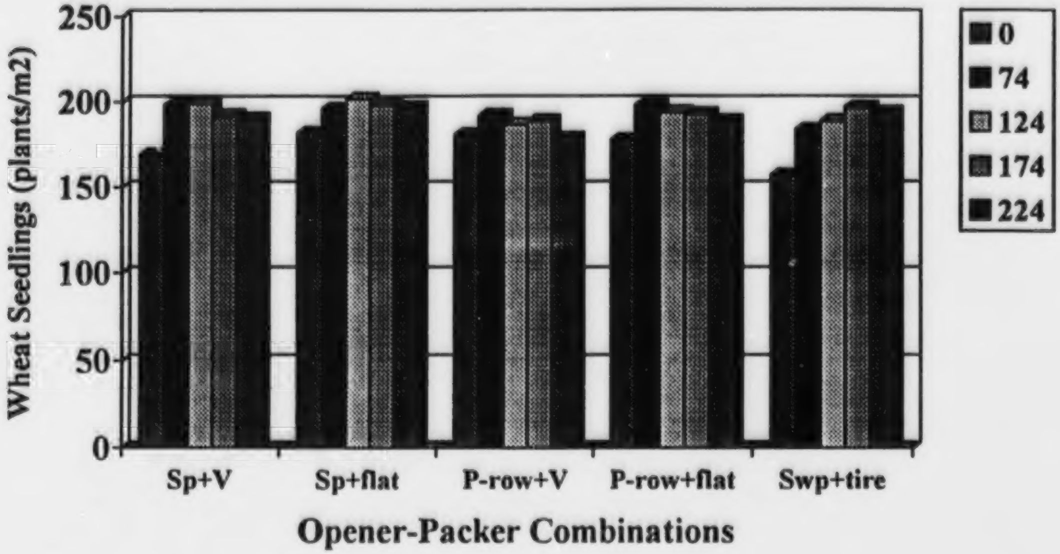


Figure W2. Wheat grain yield opener-packer by packing pressure response – mean for 9 site-years, 1997-1999.

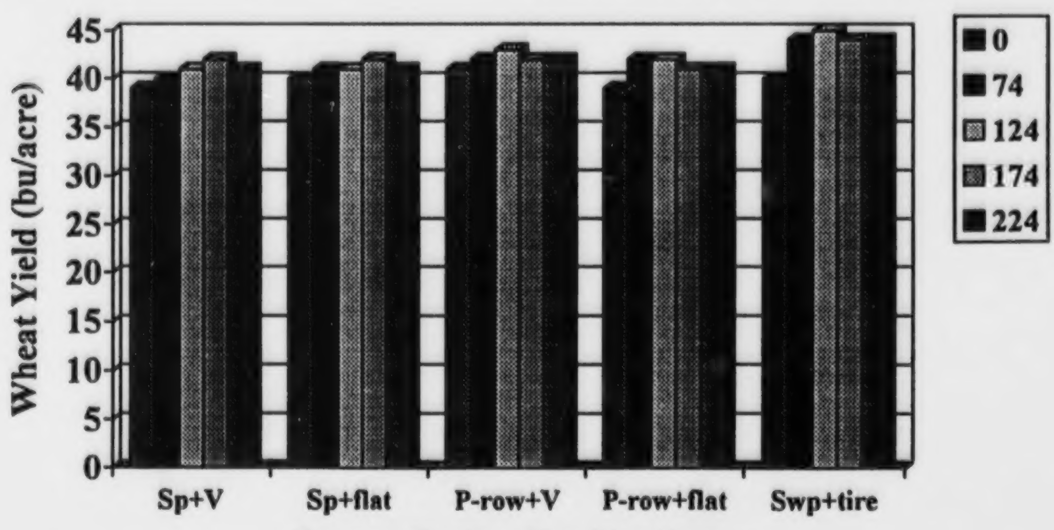


Figure W3. Wheat seedling response to packing pressure – Mean for 9 site-years, 1997-1999.

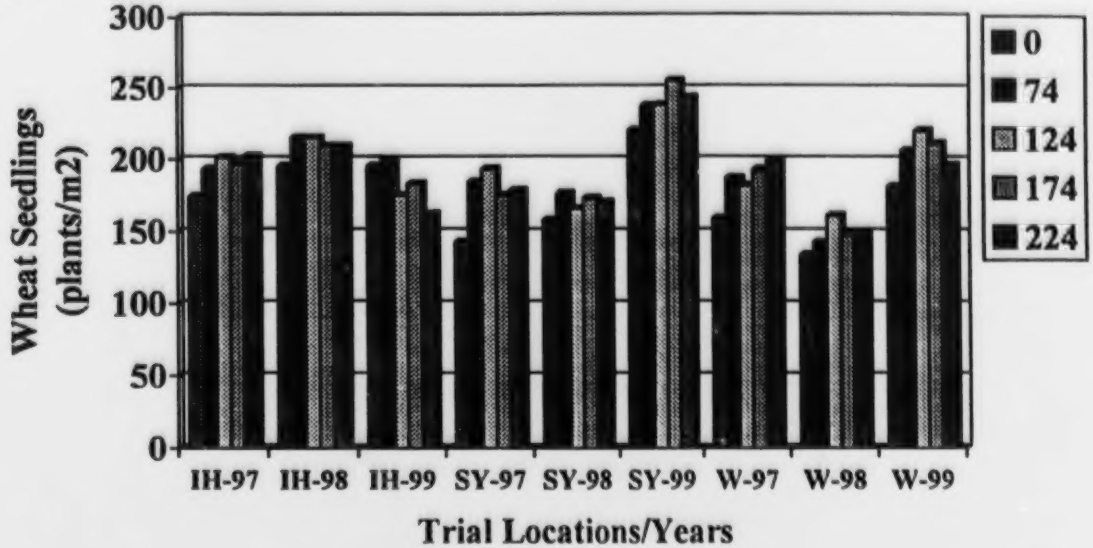


Figure W4. Wheat grain yield response to packing pressure – Mean for 9 site-years, 1997-1999.

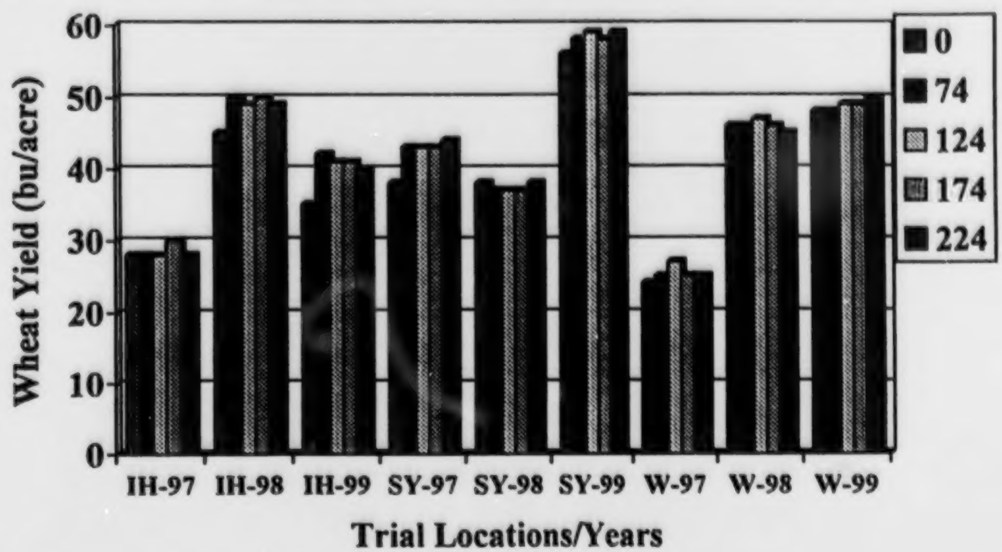


Figure W5. Wheat seedling response to opener-packer combination – Mean for 9 site-years, 1997-1999.

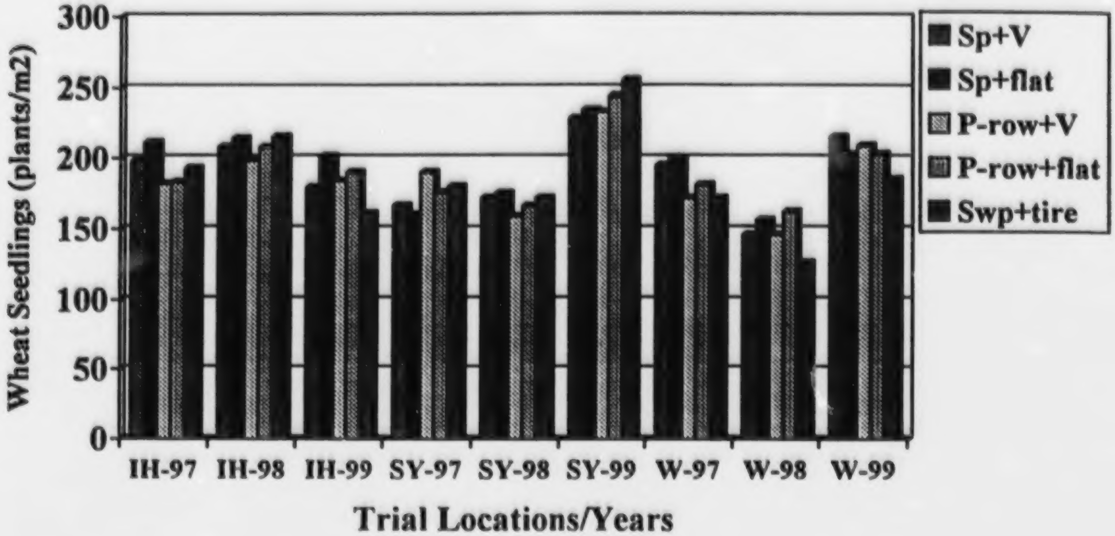


Figure W6. Wheat grain yield response to opener-packer combination – Mean for 9 site-years, 1997-1999.

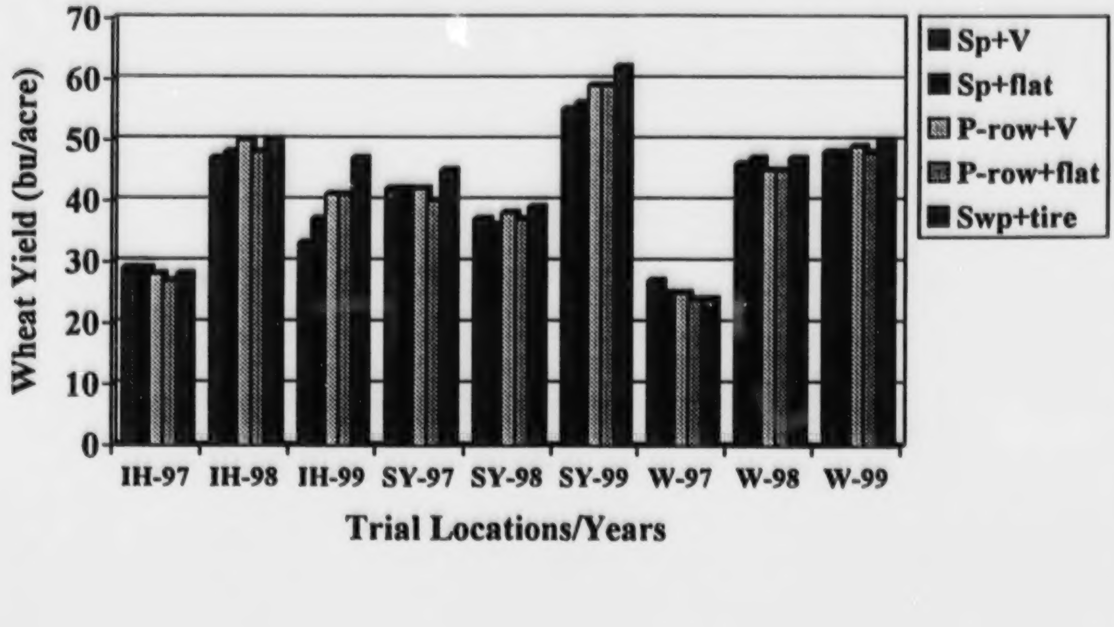


Figure C1. Canola seedling opener-packer by packing pressure response – mean for 9 site-years, 1997-1999.

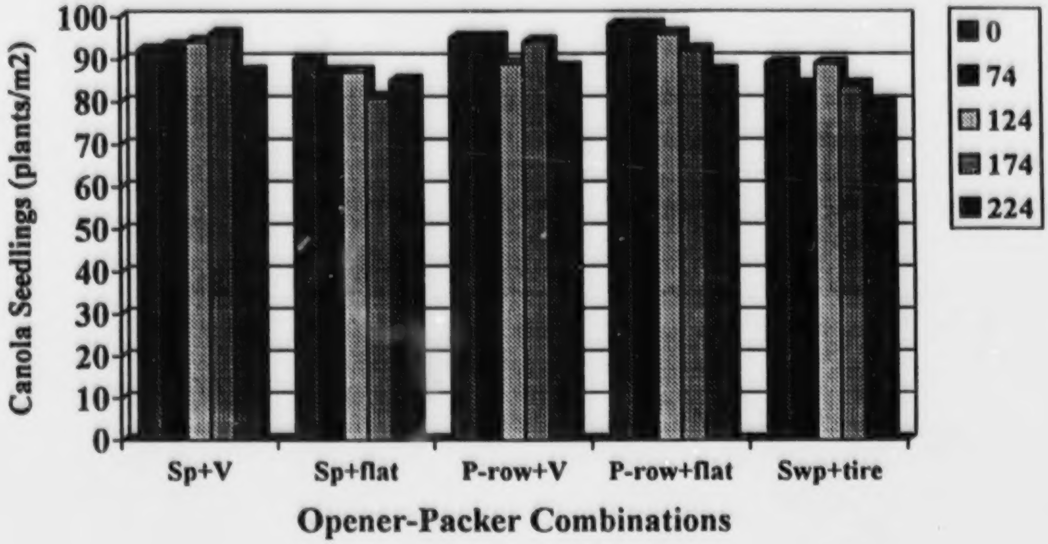


Figure C2. Canola grain yield opener-packer by packing pressure response – mean for 9 site-years, 1997-1999.

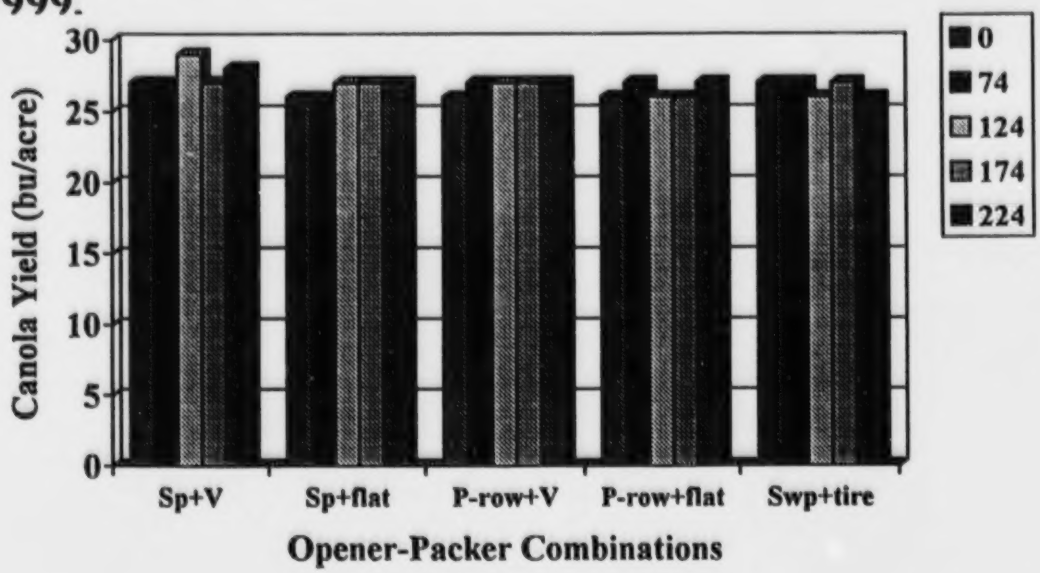


Figure C3. Canola seedling response to packing pressure – Mean for 9 site-years, 1997-1999.

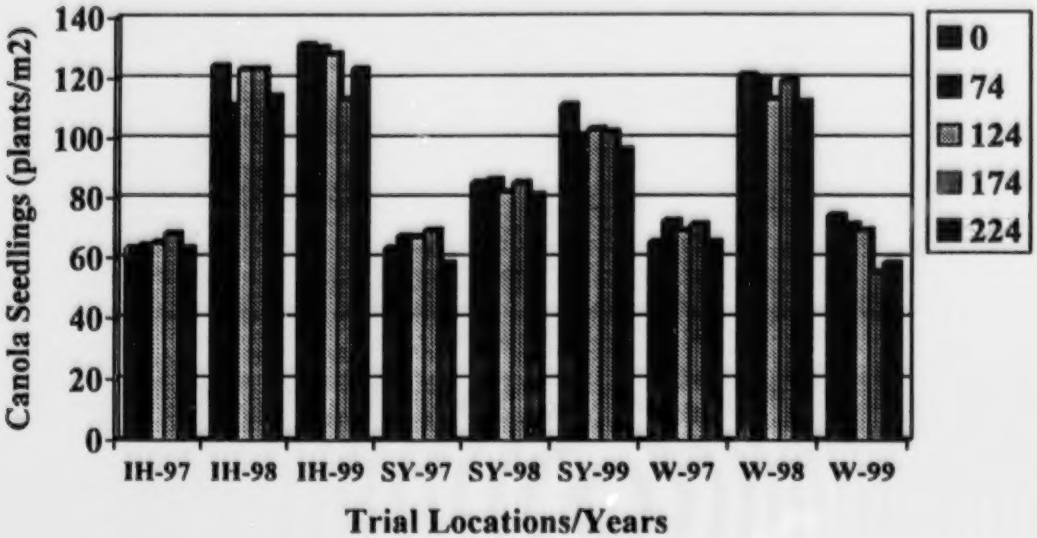


Figure C4. Canola grain yield response to packing pressure – Mean for 9 site-years, 1997-1999.

Figure C5. Canola seedling response to opener-packer combination – Mean for 9 site-years, 1997-1999.

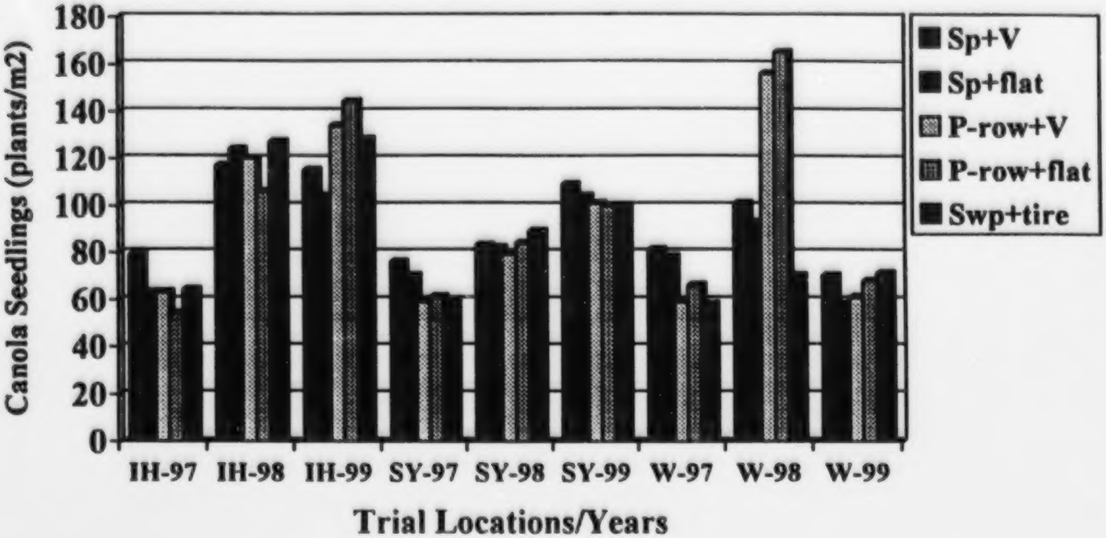


Figure C6. Canola grain yield response to opener-packer combination – Mean for 9 site-years, 1997-1999.

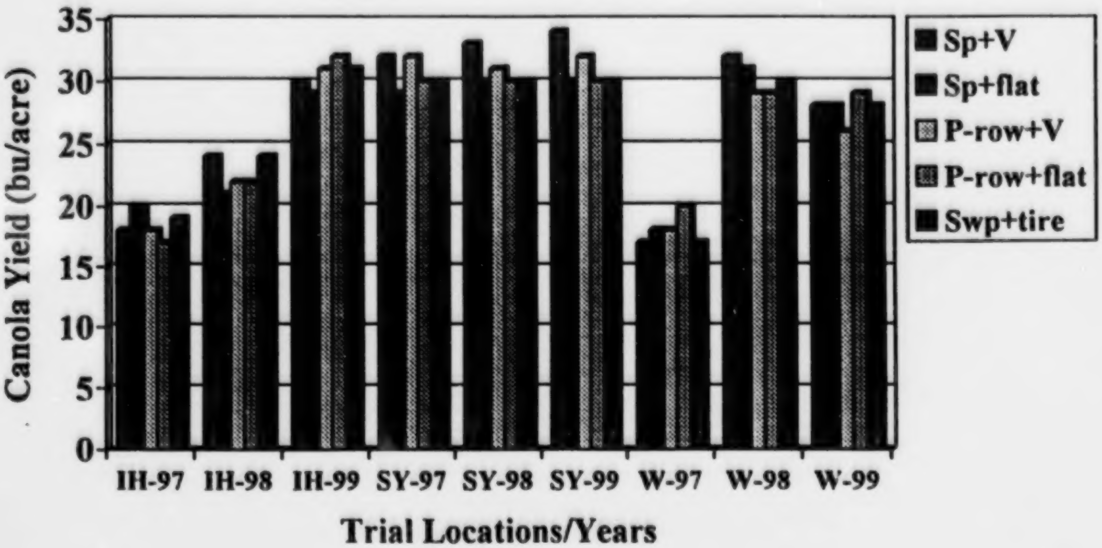


Figure P1. Pea seedling opener-packer x packing pressure response – Mean for 9 site-years, 1997-1999.

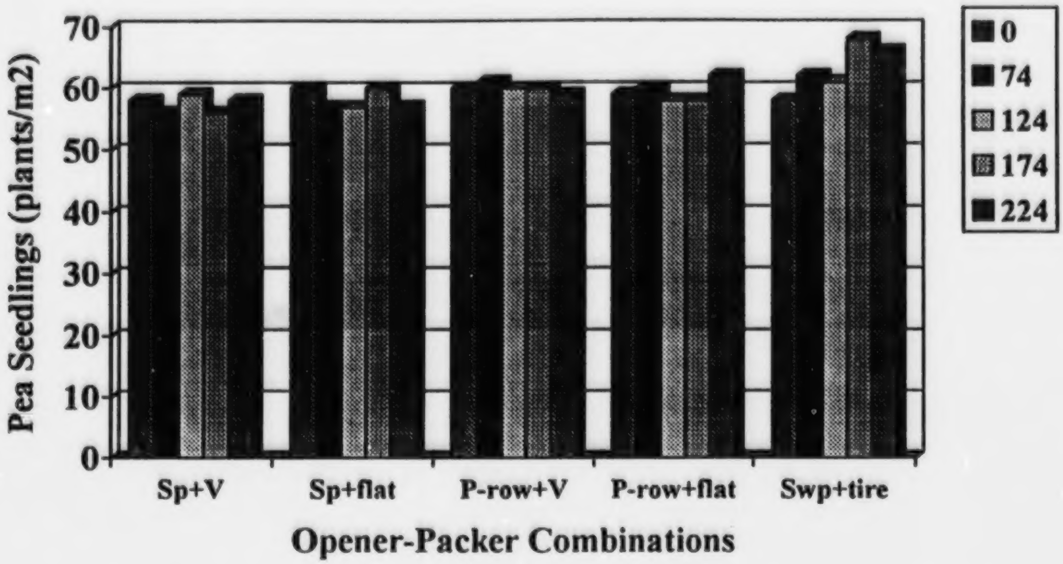


Figure P2. Pea grain yield opener-packer by packing pressure response – mean for 9 site-years, 1997-1999.

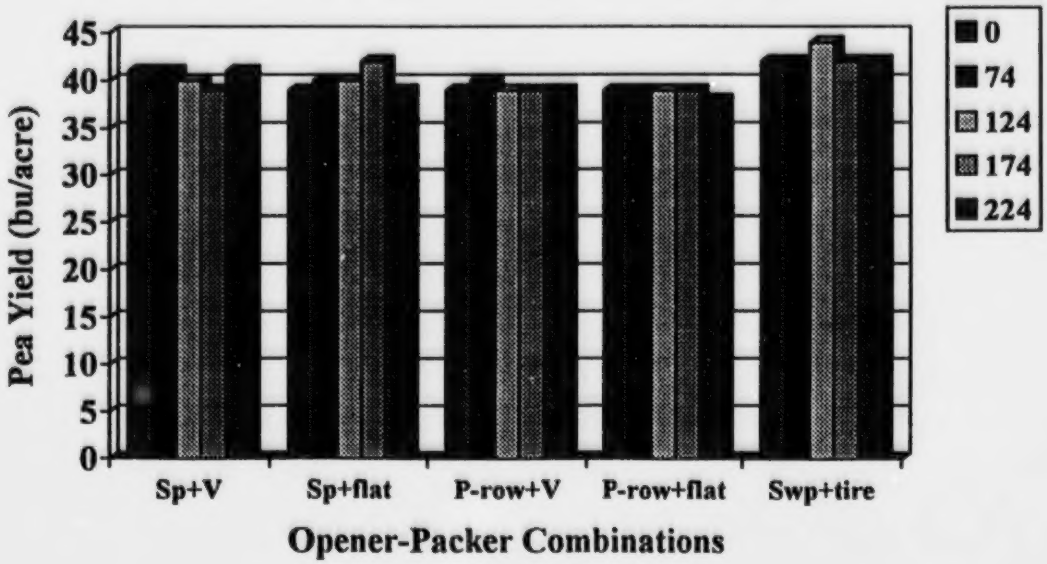


Figure P3. Pea seedling response to packing pressure – Mean for 9 site-years, 1997-1999.

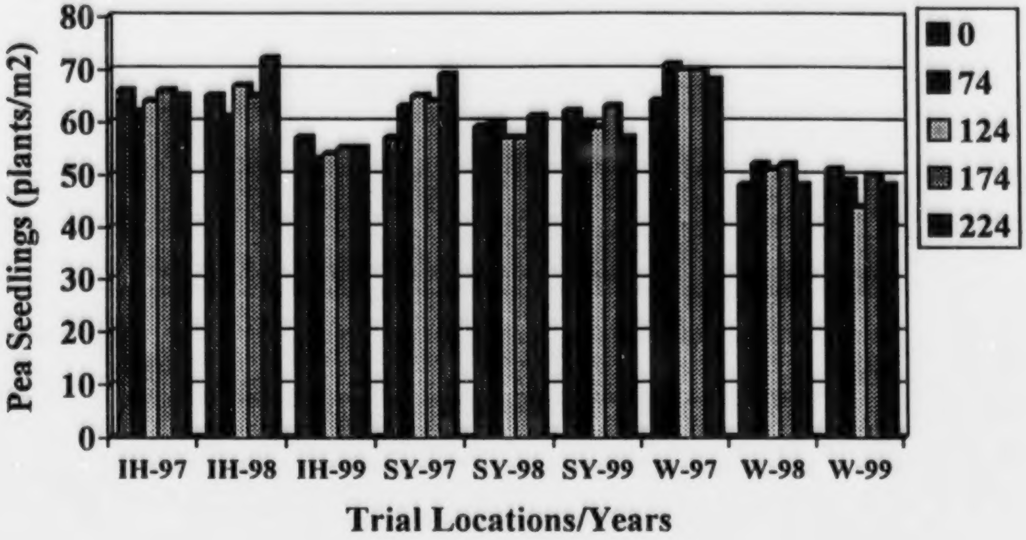


Figure P4. Pea grain yield response to packing pressure – Mean for 9 site-years, 1997-1999.

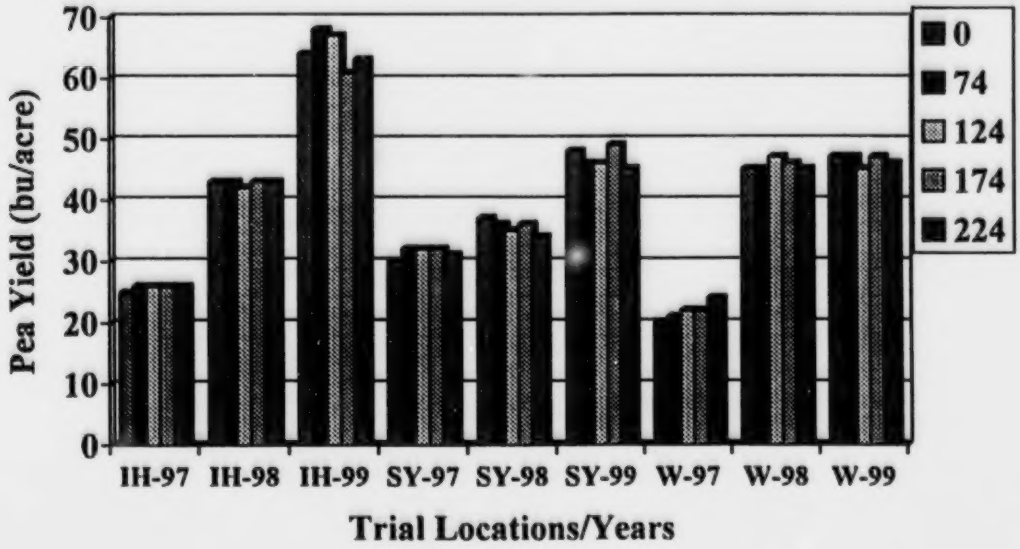


Figure P5. Pea seedling response to opener-packer combination – Mean for 9 site-years, 1997-1999.

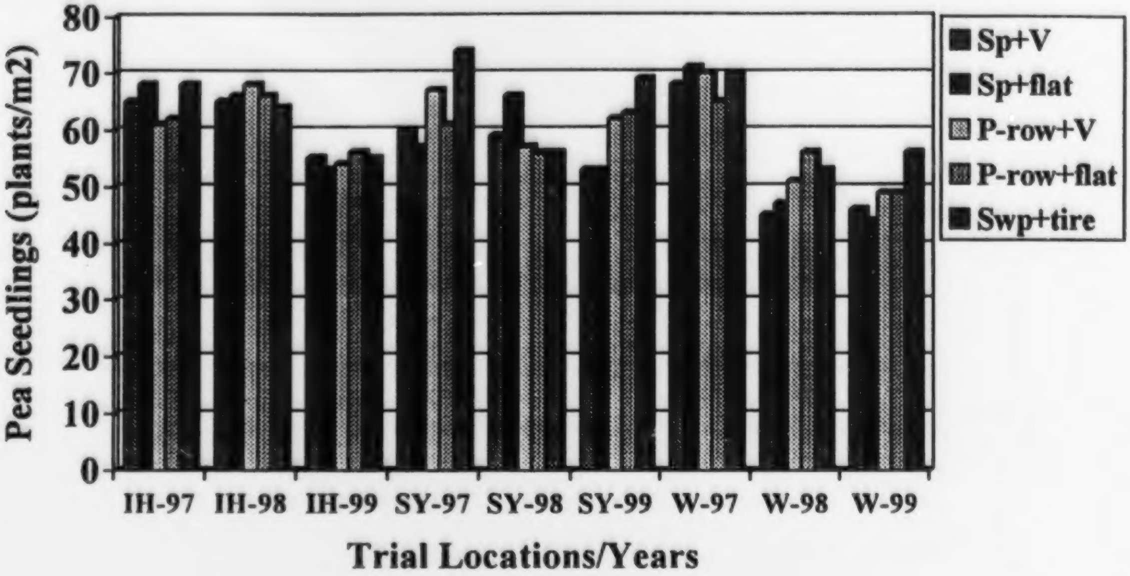
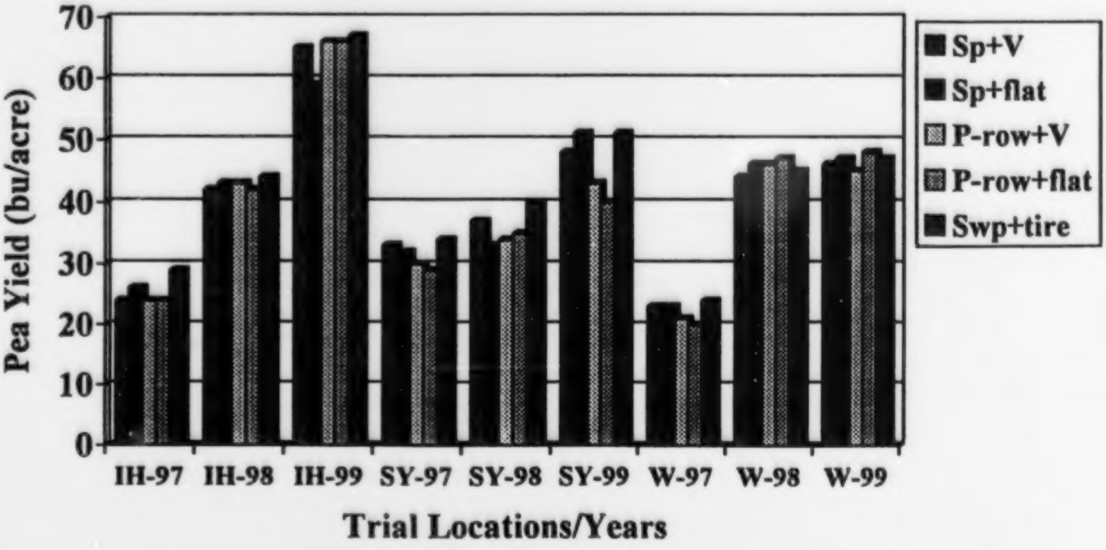


Figure P6. Pea grain yield response to opener-packer combination – Mean for 9 site-years, 1997-1999.



Appendix 1. Crop emergence and yield response across years within each location.

	Wheat Melfort Crop Stand (plants/m2	Grain Yield (bu/ac)	Indian Head Crop Stand (plants/m2	Grain Yield (bu/ac)	Watrous Crop Stand (plants/m2	Grain Yield (bu/ac)	Canola Melfort Crop Stand (plants/m2	Grain Yield (bu/ac)	Indian Head Crop Stand (plants/m2	Grain Yield (bu/ac)	Watrous Crop Stand (plants/m2	Grain Yield (bu/ac)	Peas Melfort Crop Stand (plants/m2	Grain Yield (bu/ac)	Indian Head Crop Stand (plants/m2	Grain Yield (bu/ac)	Watrous Crop Stand (plants/m2	Grain Yield (bu/ac)
Packing																		
0	174 b	44.0	188	38.2 b	158 b	39.3	86	29.4	106	23.9	87	25.6	60	38.3	63	44.1	55	37.5
74	199 a	46.1	203	39.8 a	179 a	39.8	85	31.5	102	24.3	88	24.2	61	37.9	59	45.6	58	37.8
124	199 a	46.5	197	39.3 a	188 a	41.0	84	31.4	105	23.5	84	25.8	60	37.6	62	45.8	55	38.0
174	201 a	46.1	197	40.3 a	184 a	40.1	85	30.5	101	23.5	82	25.9	61	39.1	62	43.3	58	38.4
224	197 a	46.7	191	39.1 a	182 a	40.0	78	31.0	100	24.5	78	25.0	62	36.8	64	44.3	55	38.4
Opener																		
Spoon + V	188	44.4 b	195	36.6	185 a	40.5	89	32.6 a	104	23.9	84	25.7	57	39.5 ab	62	44.0	53	37.5
Spoon + flat	190	44.6 b	209	38.1	186 a	40.3	85	30.0 c	97	23.7	76	25.5	59	38.9 ab	62	42.9	54	38.7
P-row + V	194	46.2 ab	186	39.7	176 ab	39.9	80	31.4 b	105	23.6	92	24.7	62	35.6 bc	61	44.4	57	37.3
P-row + flat	195	45.5 b	194	38.8	182 a	39.0	82	29.9 c	102	23.7	100	25.9	60	34.4 c	62	44.6	56	38.2
Sweep + tire	202	48.5 a	190	41.6	161 b	40.4	83	30.0 c	106	24.7	66	24.8	66	41.4 a	62	47.2	60	38.5
Study Mean	194	45.9	195	39.0	178	40.0	84	30.8	103	23.9	84	25.3	61	38.0	62	44.6	56	38.0
Pr > F																		
Year	**0.0001**	**0.0001**	0.3307	**0.0003**	**0.0038**	**0.0001**	**0.0001**	0.9738	**0.0001**	**0.0017**	**0.0245**	**0.0001**	0.5723	**0.0002**	**0.0032**	**0.0001**	**0.0001**	**0.0001**
Packing	**0.0343**	0.2796	0.6884	**0.0328**	**0.0220**	0.2530	0.1299	0.5644	0.6764	0.2529	0.2850	0.1624	0.9077	0.2800	0.1195	0.3624	0.4273	0.8892
Opener	0.5309	**0.0356**	0.1814	0.4037	**0.0429**	0.6323	0.1839	**0.0017**	0.9129	0.7024	0.5851	0.7164	0.4764	**0.0388**	0.9212	0.3606	0.2907	0.6322
Packing x Opener	0.2693	0.5543	0.8674	0.7976	0.7897	0.6960	0.0518	0.6139	0.5751	0.0916	0.8274	0.8746	0.1967	0.0541	0.1702	0.0956	0.4529	0.9276
Year x Packing	0.0551	**0.0097**	**0.0041**	0.1375	0.2574	0.4788	0.3752	**0.0095**	0.2343	0.7035	0.5777	0.7249	**0.0247**	0.1466	0.4597	0.1902	0.2005	0.2432
Year x Opener	**0.0290**	**0.0282**	0.0634	**0.0001**	0.2298	0.0671	0.1209	0.9079	**0.0001**	**0.0117**	**0.0001**	0.1241	**0.0001**	**0.0001**	0.1909	**0.0043**	**0.0115**	0.2018
Year x Packing x Opener	0.8616	0.0734	0.2394	0.7815	**0.0269**	0.6430	0.9187	0.1300	**0.0064**	0.8926	**0.0269**	**0.0280**	0.5302	0.7700	0.6446	0.7971	0.7334	0.3042
C.V.	17	7	14	13	15	10	22	12	16	15	25	14	16	12	16	13	19	12